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Promoting Research Quality to Study Mental Models of Ethics and Diversity, Equity, and Inclusion (DEI) in Engineering

Dr. Justin L. Hess, Purdue University at West Lafayette (COE)

Dr. Justin L Hess is an assistant professor in the School of Engineering Education at Purdue University. Dr. Hess's research focuses on empathic and ethical formation in engineering education. He received his PhD from Purdue University's School of Engineering Education, as well as a Master of Science and Bachelor of Science from Purdue University's School of Civil Engineering. He is the editorial board chair for the Online Ethics Center, deputy director for research for the National Institute of Engineering Ethics, and past-division chair for the ASEE Liberal Education/Engineering and Society division.

Dr. Andrew Katz, Virginia Polytechnic Institute and State University

Andrew Katz is an assistant professor in the Department of Engineering Education at Virginia Tech. He leads the Improving Decisions in Engineering Education Agents and Systems (IDEEAS) Lab, a group that uses multi-modal data to characterize, understand, a

Isil Anakok, Virginia Polytechnic Institute and State University

Ms.Anakok is Ph.D. candidate in the Department of Engineering Education at Virginia Tech. She has a Ms. degree in Mechanical Engineering at Virginia Tech, and Bs. in Mechatronics Engineering from Kocaeli University, Turkey.

Prof. Brent K. Jesiek, Cornell University

Dr. Brent K. Jesiek is Professor in the Schools of Engineering Education and Electrical and Computer Engineering at Purdue University.

Andrew Whitehead,

Andrew Whitehead received his Master's of Science from Purdue University's School of Engineering Education in Fall 2022. His research interests include diversity, equity, and inclusion and empathy within the engineering pedagogy.

Sri Sowmya Panuganti, Purdue Engineering Education

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Abstract

This paper seeks to identify and share research quality considerations associated with studying engineering faculty members' and engineering practitioners' mental models of ethics and Diversity, Equity, and Inclusion (DEI) in engineering. Our overarching research objective is to generate and synthesize mental models held by experts in ethics and DEI in engineering or engineering education. In this paper, we describe validation considerations to promote research quality with respect to "making data" and "handling data" when studying mental models. We share and rationalize decisions and iterations to research procedures that occurred during the study design and implementation. Specifically, we depict how these shifts aligned with six research quality considerations: theoretical validation, procedural validation, pragmatic validation, communicative validation, ethical validation, and process reliability. As one example, we expound upon procedural validation considerations for making data, wherein we continuously questioned and revised the flow and structure of the interview by 91) seeking and integrating internal feedback (i.e., team) and external feedback (i.e., advisory board), (2) creating memos after each interview, and (3) continuously discussing interview experiences and procedural adjustments. We offer the instrumentation (i.e., the interview protocol included as an Appendix) for cultivating conversations on ethics and DEI in engineering classrooms, amongst engineering faculty bodies, or throughout engineering organizations. Lessons from this study will also guide other researchers who study similarly complex mental models in engineering.

Keywords: ethics; engineering ethics; diversity; equity; inclusion; mental models

Introduction

ABET accredited engineering education programs require that students develop "informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [1]. Yet there are numerous views regarding what ought to be the aims of engineering education [2, 3] and which instructional approaches ought to be implemented towards these aims [4, 5]. Similarly, ABET recently included Diversity, Equity, and Inclusion (DEI) in their general criteria for accredited programs [6]. Like ethics, there are contrasting views regarding what constitutes DEI or why DEI is important in engineering education, if at all [7]. Engineering education scholars have generally pursued ethics and DEI as separate topics in engineering education scholarship [8], thereby suggesting that ways of connecting ethics and DEI is a nascent area of research and practice. Despite this nascency, there is a critical mass of scholars exploring ethics and DEI in tandem in engineering education [8-12].

While research that explicitly explores connections between ethics and DEI in engineering is relatively uncommon [13], engineering professional societies have codified DEI-related issues in ethical canons [6, 14]. And although this overt focus on ethics and DEI has become more explicit in recent years, the preamble to the National Society of Professional Engineers' (NSPE) [14] code of ethics has stated for decades, "The services provided by engineers require honesty, impartiality, fairness, and **equity**, and must be dedicated to the protection of the public health,

safety, and welfare" (emphasis added). Likewise, ASCE has recently integrated a specific focus on equity with/for peers into their code of ethics [15]. Non-discrimination and anti-discrimination (each of which are ostensibly DEI-related) were recently introduced into the IEEE code of ethics [16] and NSPE code of ethics [17], respectively. These are a few examples of how DEI might manifest within engineering ethics, but importantly, these are but two views among many potential mental models regarding ethics/DEI connections [12].

Our overarching study aims to explore mental models at the engineering ethics/DEI intersection, identify commonalities and distinctions across ethics and DEI scholarly communities, and identify alignment between practitioner and academic communities. Mental models refer to the decision-making processes and structures that individuals possess, much of which may be tacit. Mental models thus refer to a person's internal representations of (a) state, (b) form, (c) function, and (d) purpose of a system [18]. As Jones et al. [19] stated, "A mental model is a simplified representation of reality that allows people to interact with the world" (p. 5). Colloquially, they are cognitive structures that individuals use to represent how they view the world around them [20]. Mental models can also take the form of narratives of events and actions that evolve over time and are important when operating in complex systems because they facilitate understanding and control within those systems [21, 22]. As a research method, mental model elicitation encourages individuals to describe, explain, and predict aspects of systems, such as socio-technical systems implicated in engineering or the concepts that manifest within such complex systems (such as engineering ethics and DEI). Morgan et al. [23] provided one approach to mental model elicitation, which involves evoking and synthesizing "expert models" (p. 104). We employ this expert-elicitation tactic in this study.

Mental models have been studied in numerous contexts in engineering education [24]. An example study on mental models in engineering ethics comes from Katz [4], who explored mental models among engineering instructors regarding engineering ethics education. Therein, Katz explored and extracted "areas" of mental models in engineering ethics education, including definitions of ethics, pedagogical approaches, and learning processes. Notably (at least when considering the aims of this study), the terms diversity, equity, and inclusion were not explicit in Katz's study findings. We infer that there are multiple potential reasons for this, such as the study protocol not prompting participants to consider DEI or participants simply not associating DEI concerns with engineering ethics education. This study takes up this research methodology and line of inquiry, with the ultimate objective of bridging discourses across ethics/DEI and academic/practitioner communities regarding how engineering ethics and DEI relate.

Study Overview

Our objective in this study was to identify research quality considerations associated with studying engineering faculty members' and engineering practitioners' mental models of engineering ethics and Diversity, Equity, and Inclusion (DEI). A focus on research quality strategies helps ensure that our overall methodology is authentic to individual's social realities, provides accurate accounts of their lived experiences, and provides useful extensions of theory (here, how engineering ethics and DEI connect in engineering). This paper thus explores and elucidates research quality considerations associated with our research design and implementation. Identifying what strategies promote research quality is, in itself, a critical topic

of discussion in engineering education. By considering and elucidating our strategies to promote research quality whilst investigating mental models, we hope to provide guidance for other educators who perform similar qualitative research studies.

In the overarching study, we employ mental model elicitation activities to identify and compare how academics and practitioners view engineering ethics, DEI, and connections between these topics in engineering. In the overarching study, we aim to address the research questions, "How are engineering ethics and DEI related based on mental models elicited from academics active in research on ethics and/or DEI?" and "How are engineering ethics and DEI related based on mental models elicited from a diverse cross-section of industrial practitioners who bring expertise in ethics and/or DEI?"

One of our guiding assumptions is that DEI scholarly communities and engineering ethics scholarly communities are distinct [12]. As a result, this work aims to bridge discourses across these two engineering education communities. We suspect that there are many other communities or areas in engineering education that have commonalities but are fundamentally distinct or divided. Thus, other scholars might employ our research methods herein to identify modalities for connecting disconnected fields that share common interests and goals.

We employed Ford and Sterman [25] and Morgan et al. [23] to guide the research design and we utilized Walther et al. [26] to develop strategies in pursuit of qualitative validation. Validation strategies identified by Walther et al. [26] vary between two primary activities (i.e., making data, handling data) and six validation aspects (i.e., theoretical validation, procedural validation, communicative validation, pragmatic validation, ethical validation, process reliability). Walther and colleagues' [26] quality framework draws attention to the pervasiveness of validation throughout the entirety of a research project, and they offer six validation types to provide guidance for promoting research quality. We take up these quality considerations in the remainder of the study, but first we briefly offer ways of operationalizing the key phrases we investigate herein.

Operationalizing "Engineering Ethics" and "Diversity, Equity, and Inclusion"

In this study, we introduce and interrogate two concerted terms or phrases: (1) Engineering Ethics and (2) Diversity, Equity, and Inclusion (DEI). We do *not* presuppose how participants ought to define these terms, but rather we ask participants to unpack these terms during the interview (see Appendix). Thus, in our analysis, we aim to identify how participants operationalize these terms. We will bring a deductive set of codes based on a recent analysis of engineering education literature [13] to guide our coding of participants' views, which we briefly unpack in the following paragraphs.

In a recent systematic review, we reviewed scholarship that connected ethics and DEI in engineering and we generated codes to capture how authors operationalized terms [13]. With respect to ethics, we generated three sub-categories (professional ethics, topical ethics, and personal ethics) within an overarching category that we labelled "ethics." Each sub-category included more specific codes. For example, we coded distinct types of professional ethics, including computer science ethics, data science ethics, and engineering ethics. Herein we defined

the engineering ethics code as the *ethical obligations or considerations specific to the profession of engineering or being a professional in engineering.* While any interview analysis shared in this paper is preliminary, during interviews, we have observed that engineers tend to see engineering ethics as similarly nested within professional ethics. Moreover, many practitioners tend to view ethics as distinct from morality, which participants often view as largely subjective.

We similarly generated codes to capture ways of operationalizing DEI in the same literature. Here, we developed an overarching category (DEI) with three sub-categories (Diversity, Equity, and Inclusion-Focus). We observed that many authors focused on individual DEI terms rather than "DEI" as a phrase [13]. We developed (1) four codes on diversity, including experience & thought (defined as variations based on prior experiences and ways of thinking), demographic (defined as variations based on demographic backgrounds or characteristics), global (defined as variations based on global geographic region), and disciplinary (defined as variations based on disciplinary background); (2) two codes on equity, including "justice-related" and "access-related," and (3) three codes on the domains of inclusion, including engineering processes (i.e., ways of thinking and acting in engineering), higher education, and the workplace. In our interview design, we foresee our concerted focus on "DEI" during the interview (rather than diversity, equity, or inclusion alone) will lead to distinct and holistic operationalizations of DEI.

Finally, in our prior study [13], we generated connections between ethics and DEI in the literature. We developed three primary themes (each with three sub-themes) to capture connections: (1) Lenses for connecting ethics and DEI; (2) Roots that inform Lenses; and (3) Engagement strategies to promote connections. We will utilize these findings, alongside Katz'[4] study findings on ten "areas" of mental models in engineering ethics education (e.g., where to teach engineering ethics, who should teach engineering), as a deductive starting point for synthesizing faculty members' and practitioners' mental models in this study.

Quality Considerations Associated with <u>Making</u> Data

Theoretical validation addresses the "fit" between social reality and the theory we aim to test or develop [27]. With respect to making data, theoretical validation asks, "What is, in terms of scope and nature, the specific social reality we want to investigate?" [27, p. 3] We chose to focus on the topics of "engineering ethics" and "Diversity, Equity, and Inclusion." Our aim in this work is to evoke and synthesize mental models regarding how engineering ethics and DEI connect in engineering. Our working theory is that the topics ("engineering ethics" and "DEI") connect but there is widespread variation in *how* individuals perceive these topics in and of themselves, as well as how they relate.

We bring specific concepts and phrases (i.e., "engineering ethics," "DEI") to the study design, and we aimed to consistently prompt these phrases throughout interviews (see Appendix). By focusing on engineering ethics, we intended to draw discussions to issues, codes, or principles specific to engineering rather than personal morality or general concerns of any profession. We chose the phrase "DEI" based on its increasing use in engineering and engineering education, although we recognized that there exist other acronymized conceptions of these topics. We posited, a priori, that the three terms (D-E-I) play critical roles in realizing a shared sentiment that goes beyond the individual terms when used in isolation, but we did not presuppose what

those roles constitute. Rather, during interviews, we offered opportunities for participants to share how they understand the terms and whether (or not) the phrase resonated. At the conclusion of each interview, we asked participants to discuss D-E-I individually and to voice the relative import of each DEI term to the overall acronymized phrase. The final interview section asked participants whether other like-terms ought to be use in conjunction with DEI (we did not provide such terms to participants, but we have seen terms including but not limited to accessibility [28] and justice [29]).

The above considerations draw attention to the topics we investigated and how our choices of framing influenced theoretical validation. Participant selection also strongly influences which social realities we explore. We collected perspectives from experts in ethics *or* DEI, which we ascertained via purposeful sampling wherein we leveraged extant scholarship (for academics) or leaders within organizations (for both academics and practitioners) to identify potential candidates. While this enabled us to approximate potential expertise, we also operationalized "expertise" by prompting participants to self-report their levels of experience and perceived expertise on each of the topics (ethics, diversity, equity, inclusion). We hypothesized that most participants would consider themselves as experts in ethics or DEI and that participants with variable levels of expertise might respond to interview prompts in distinct ways.

Procedural validation focuses on study procedures, including their likelihood of effectively extracting how theory manifests in individuals' social realities. Procedural validity prompted us to ask questions such as, "What are appropriate means by which we can 'see' the social reality under investigation?" and "What features can we build into the inquiry to mitigate threats to an authentic view of the social reality?" [27, p. 3] Firstly, we chose to conduct single two-hour long interviews (rather than employing quantitative or psychometric instrumentation or collecting other forms of qualitative data). We iterated on the interview protocol by developing an initial draft of a protocol, having one interviewer practice it with another, revising the protocol, implementing pilot interviews with three graduate students with workforce experiences, revising the protocol again, soliciting feedback from our advisory board (who brings expertise in ethics and DEI), revising yet again, implementing initial interviews, writing reflective memos after each interview, and continuously asking which aspects of the interview process were working well or needed revision. We were thus constantly iterating and discussing interpretations of the effectiveness of the protocol in light of the research questions and the interview responses. Iterations that occurred at the interview stage were minimal but intended to ensure additional prompting in critical areas. As one example, based on team discussion, one interviewer realized that they often did not give sufficient time to the final section of the interview and began more purposefully transitioning throughout interview sections at prescribed time points.

We designed the interview protocol in alignment with Ford and Sterman [25], who suggested three sequential phases to elicit mental models: (1) positioning intended to "establish a context and goals for the description process" (p. 314); (2) "description" wherein participants visualize, verbalize, textually depict, and graphically depict their views; and (3) "discussion" wherein participants share and discuss their written and visual artifacts with a group. Likewise, the interview protocol included three overarching steps with slight adaptations. (e.g., we refined the discussion step for individual interviews rather than group-based interviews). Below, we highlight critical choices in the design and implementation of interviews for each section.

In Section 1, "positioning," participants share a brief background on the work they do and why they do it, brief conceptions of the topics (engineering ethics, DEI), two to three experiences with each topic, and then describe an experience at the intersection of engineering ethics and DEI. The section thus develops rapport before interviewer/interviewee and positions the interviewee for the mental model elicitation activities by promoting intensive reflection on their work experiences related to the topics. This section generally was between 45 and 60 minutes.

In Section 2, "description," participants (1) draw and verbalize how engineering ethics and DEI connect, (2) respond to a DEI case regarding the retention of underrepresented employees, and (3) review and critique the IEEE code of ethics. This section thus prompts three different response modalities. To start, participants use a writing utensil to draw on paper the relationship between engineering ethics and DEI. We chose to have participants draw after having one interviewer practice the protocol with another. At the time, we were considering asking participants to use modelling software (e.g., Miro) that was familiar to them. Based on this pilot interview experience, physically drawing on paper felt more appropriate than virtual modelling. We rationalized that drawing would eliminate time devoted to learning a new technology and that drawing activities employ different parts of the brain than verbal responses would. After the drawing activity, participants responded to a DEI case on organizational retention of underrepresented employees, which we adapted from "Dirty Diversity" [30]. Finally, participants interrogated the 2020 IEEE Code of Ethics [16] and identified if any clauses or codes felt out of place. In sum, this section roughly ranged from 30 to 45 minutes.

Third, "summation" asked participants to reflect on their conceptions of ethics and DEI terms and their mental model drawing. This section prompted participants to interrogate their prior responses and to summarize and expound upon their conceptions of the terms. First, we asked participants to distinguish between ways of framing ethics (e.g., engineering ethics versus personal ethics; ethics versus morality). Next, we asked participants to define individual DEI terms and voice their relative import. We close each interview by asking participants if they would like to update their visual mental model drawings (most participants choose to forego updating their drawing). This section roughly ranged from 15 to 30 minutes.

Taken together, the interview begins by evoking participants' experiences (i.e., Section 1 or positioning), these experiences provide context for mental models (i.e., Section 2 or description), and closing activities that gather additional insights and conceptions from participants on terms that were used throughout the interview. In sum, the mental model data includes experiential data that informs one's mental model, graphical and verbal descriptions of one's mental model, an application of one's mental model to extant DEI and engineering ethics concerns, and a post-hoc reflection on terms to expound or summarize conceptions of individual parts of one's mental model. While the interview itself is at the heart of our procedural concerns, post-interview member checking will also provide participants with an opportunity to add insights to their prior responses, revise statements, and ensure aspects of the interview transcript were appropriately de-identified.

Communicative validation "concerns the integrity of the interlocking processes of social construction with the relevant communication communities" [27, p. 3]. Guided by communicative validation, we ask questions like, "How can we authentically co-construct

meanings of participants' social realities on their own terms?" [27, p. 3]. Our intended participants bring diverse life experiences and expertise. We thus framed experiential questions broadly. For example, during Section 1, we inquired into experiences with engineering ethics and DEI in participants' "work," thus freeing them to articulate experiences in teaching, research, practice, service, or in a few instances, their everyday lives (although our framing seems to have minimized discussion of personal life experiences). While we guided participants to focus on "engineering ethics" and "DEI" from the outset of the interview, depending on the interviewee, the remainder of the interview could naturally shift to a focus on "ethics" more broadly (i.e., not specific to engineering or engineering ethics) or select aspects of DEI (e.g., D&I seemed familiar to many practitioners whereas DEI seemed to be a new acronym for many practitioners).

We posited that how participants describe and understand these phenomena would vary by participants' experiences and expertise. Initially, our protocol started with a concerted emphasis on conceptions, including how terms like ethics, engineering ethics, and morality might differ. We shared a version of the protocol with our advisory board, wherein we included a concerted line of questioning intensively exploring such conceptions. We received feedback suggesting that many interviewees might feel unsure, stuck, and uncomfortable responding to such questions at the start of the interview. One board member (Cindy Rottmann) shared that in interviews they had conducted with engineering educators, interviewees generally became engaged and spoke confidently about their experiences with topics even when lacking precise ways of conceiving these topics. Thus, we incorporated this feedback and reduced questions associated with conceptions in section 1. Instead, within section 1, we asked for an overall conception of "engineering ethics" which was then followed by asking participants to share two to three experiences with engineering ethics. Immediately thereafter, we asked participants, "When you think of this phrase, "DEI", what does this mean for you?" Next, we asked participants to articulate experiences with DEI. We thus retained a brief focus on conceptions in Section 1, which helped the interviewers better understand how and to what extent individuals brought conceptions of engineering ethics and DEI to the conversation. Nonetheless, we still felt the conceptions were important for understanding individuals' mental models, so we reserved the more direct conceptual questions for the third and final section of the interview.

Ford and Sterman [25] indicated that it is critical to elicit multiple ways for individuals to express their mental models. We thus elicited responses from participants in multiple ways (i.e., traditional interview responses; drawing) and at multiple time points (e.g., post-interview member checking). We will use member checking in two ways. First, we have shared transcripts with participants and therein asked participants if they would like to refine or expand upon views or responses. Second, we intend to share a compilation of all results and elicit a member checking survey, and in that survey, we intend to ask participants to identify the extent to which results resonate with them or if they feel any of their perspectives or experiences were missing.

Pragmatic validation seeks to ensure that the theory applied or generated has empirical meaning or impacts. Pragmatic validation prompts us to ask questions like, "What assumptions do we make about the nature of the reality under investigation?" [27, p. 3] Based on prior studies that have elicited mental models, we presumed that well-designed interviews would provide a valid modality to understand participants' social realities. We also bring an important philosophical assumption that *knowledge is socially constructed*. The nature of our data

collection involves facilitating the individual construction of engineering ethics and DEI connections and then member checking to socially construct, develop, and promote shared language and understandings. We brought many other assumptions to this study, including that (1) there are different ways of connecting ethics and DEI in engineering, (2) there will be variation in ways of connecting these topics, and (3) that we will be able to elicit common views via mental modelling activities. We can already foresee that many members have numerous minoritization experiences that the compiled data cannot do justice to, and we are considering ways to share such stories while respecting the anonymity and autonomy of interviewees.

Ethical validation draws attention to the research team's ethical obligations and involves actively seeking approaches to "do justice to the participants, co-investigators, and readers of our research" [31]. Ethical validation encourages us to ask questions like, "How can we ensure legitimate and responsible decisions to inform our interpretation?" [27, p. 3] or "What are the impacts of our interests, biases, preconceptions, or intentions on this investigation?" [31, p. 375]

We brought a concern that data could have unforeseen negative impacts on participants who have candidly shared their critical experiences. Thus, with respect to doing justice to our participants, we have developed multiple time points for participants to respond to questions during the interview, ways for participants to 'check' their individual transcripts post-interview, and we will perform a final member check of study findings before disseminating findings to external audiences. These steps aim to ensure that participants' feel the data and the results are satisfactorily de-identified *and* that they provide accurate portrayals of participants' social realities and experiences.

With respect to doing justice to the co-investigators, we sought strategies to ensure the effective inclusion of our team members throughout the research process. One primary strategy to this end involves constant communication, largely through consistent meetings but also seeking input on all research products and artifacts. Thus, during meetings, individuals shared emergent insights and collaboratively worked through conflicts and uncertainties, including "ethically important moments" [31, p. 376]. Interviews themselves (schedule permitting) have included a lead interviewer and a supporting interviewer, thus reducing the pressure on the lead interview to not miss any important follow-up questions, and affording opportunities for interviewees to hear questions from two different perspectives. Post-interview, the supporting interviewer drafts a peer memo to capture what worked well, what could work better, and key takeaways. These memos become another vehicle of communication across research team members to ensure that our large research team can effectively build on and learn from teammate's perspectives.

With respect to doing justice to the reader, we recognize that our individual biases will influence the making of data, including participant selection, the quality of interviewer-interviewee interactions, and the line of questioning in interviews. This intensive depiction of our research process and approach is intended to help us communicate our research design in a comprehensive manner so that readers can, ideally, develop a holistic understanding of our strengths and limitations, as well as (should the reader aspire to) replicate our procedures.

Process reliability aims to minimize improper influence of extraneous variables. To address process reliability, we ask questions like, "How can we mitigate, as far as possible, random

influences on our process of seeing the social reality under investigation?" [27, p. 3] Our research approach was interpretive, iterative, and collaborative in nature. Thus, the authors' positionality and associated biases influenced our research strategies and study findings. The PIs of our research team primarily identified as experts in the engineering ethics space, and thus we sought feedback and insights from an advisory board with expertise in engineering ethics and expertise in DEI in engineering. Other process reliability checks we have implemented include (1) developing a shared checklist for pre-interview, interview, and post-interview activities; (2) developing post-interview memos to share new insights and procedural considerations to guide continuous improvement; (3) meeting frequently to discuss data collection insights; (4) revisiting our participant pool to ensure diversification across appropriate sectors of engineering education and the workforce; (5) having multiple coders listen to audio to ensure that audio is accurately transcribed; (6) sharing transcripts with research participants to again check accuracy of statements and appropriateness of de-identification; and (7) member checking by sharing aggregated responses to ensure individual viewpoints are not minimized or excluded.

Quality Considerations Associated with <u>Handling</u> Data

Our overall objective in "handling data" is to ensure that we share and disseminate data and results of analysis in ways that provide a holistic understanding of the theory under investigation, as well as incorporate individuals' experiences in appropriate ways.

Theoretical validation prompts us to ask, "How do I [we] know that the findings make a meaningful contribution to the relevant body of theory?" [27, p. 3] At the time of this writing, where we have completed 50 interviews, findings are preliminary, but we have delivered multiple talks building on our research procedures. These talks have largely been interactive and intended to prompt communal dialogue on ethics/DEI by building on our protocol. Thus, while results are emergent, we offer that the protocol itself (see Appendix) to promote reflective dialog, pointing the way toward shared understandings of ethics, DEI, and their relationship in departments or workplace organizations. ***Hence, the protocol itself is one primary take-away for the reader of this study***. For those who wish to employ the protocol in group settings, they might shift Section 3 to a group discussion format, as in Ford and Sterman [25].

Procedural validity prompts us to consider, "What features can we design into our process of interpretation to mitigate the risk of mis-constructing the social reality of our participants?" [27, p. 3] Regarding advancing theory in ways aligned with participants' social realities, we infer that responses to compiled results among participants will be essential. Should participants share that the results resonate with them via member checking (which we will design as a Qualtrics survey with Likert-type responses and open-ended responses), we will feel confident that we have not mis-construed participant experiences. Conversely, should participants feel that the compiled data and results do not effectively represent their views, we feel it will be appropriate to engage in follow-up dialogue and find alternative mechanisms to share participants' lived experiences and mental models. We also recognize that, given the rich nature of the protocols and interview responses, we may need to pursue additional lines of investigation beyond mental models alone. For example, we feel that individuals who share experiences with workforce or everyday discrimination also share particularly unique mental models. Thus, while exploring mental

models is our primary research focus, the undergirding experiences that inform such unique mental models may warrant a separate concerted research focus.

Guided by **communicative validation**, here we ask, "How can we construct our findings within the meaning conventions of the relevant research community [or communities]?" [27, p. 3] Interactive sessions, where we share preliminary findings with academics and practitioners, provide opportunities to identify whether our process of social construction is understandable and aligned with extant conventions in the field of engineering ethics or the sub-areas of engineering ethics or DEI. Other strategies we have pursued have included attending to other artifacts with academic and professional settings that depict meaning conventions [12]. For example, codes of conduct within organizations sometimes include explicit DEI language, like how DEI manifests in engineering ethics codes.

With respect to **pragmatic validation**, we ask questions like, "How meaningful are our interpretations for the social reality under investigation?" [27, p. 3] Keywords offered by Walther and Sochacka to consider here include "insight, resonance, change" (p. 3). It is necessary to name the social worlds that our study interrogates. For example, we anticipated and have preliminarily found that many experiential connections among academics are related to teaching, experiences among practitioners generally involve workplace encounters, but both groups sometimes refer to service roles. Thus, we will question whether the mental models themselves best represent select phenomena in more specific contexts or settings. For example, discourses among academic interviews might be directly associated with the phenomena, "engineering ethics education," like in Katz [4], whereas mental models derived from practitioners may be closer to "ethical engineering practice" as situated in workplace environments [32]. Conversely, some practitioners may focus on "D&I" rather than "DEI," which may bring subtle but critical shifts in foci and mental models. Developing clarity around the exact phenomena and the aligned social realities will help us identify how best to position findings within those spaces.

Ethical validation asks us to identify whether "our findings do justice to the lived realities of our participants" [27, p. 3]. As we construct and disseminate research findings, this is an ongoing challenge. As is the case with many qualitative studies, it is difficult to present a sufficiently thick but concise description to authentically represent the many nuances in participant experiences and mental models. Conversely, in instances where it is important to provide context for readers, reporting details that are *too* specific may sacrifice anonymity that may be necessary to ensure no harm results from an individual's participation in the study. Member checking and sharing results before disseminating are critical avenues to promote participants' autonomy to decide whether they feel results are acceptable, accurate, and broadly shareable. This will also allow for participants to provide feedback on whether the results effectively "engage diverse audiences who have a stake in the social reality investigated" [30, p. 375].

Finally, **process reliability** prompts us to ask, "How can we document and authentically demonstrate the dependability of our entire process of investigation?" [27, p. 3] We used a shared and password-protected cloud file sharing system to organize thoughts and activities among our multi-member research team. Within this folder, we have developed sub-folders to track all activities associated with the study, including but not limited to (1) recruitment

materials to invite prospective participants, (2) individual participant folders which include interview checklists, transcripts, interview notes, post-interview memos, participant mental models; and (3) spreadsheets to track interview progress, transcription progress, and correspondence with participants. Collectively, these materials enable us to refer to our earlier thinking as we socially construct novel insights.

Closing Discussion

This paper shares how we have sought research quality in the making and handling of data to elicit mental models regarding connections between multiple complex phenomena (ethics, diversity, equity, and inclusion) among engineering practitioners and engineering faculty. Mental model eliciting activities can help unmask hidden or implicit connections between these topics. By collectively analyzing experts' responses, we hope to create bridges in discourses across academic/practitioner spaces and across the ethics/DEI topics.

In this paper, we explored six validation aspects associated with making versus handling data. In considering theoretical validation, we justified our choices regarding ways of framing topics (i.e., "engineering ethics," "DEI") and the social realities we sought to explore. In considering procedural validity, we articulated the alignment of our protocol with extant methods in mental model elicitation and justified our methodological decisions based on the topics and social realities we explore. Communicative validation tactics included soliciting feedback from participants at multiple time points as well as external feedback on the research design and emergent results. Pragmatic validation has prompted us (and will continue to prompt us) to ask, "For which social realities can we accurately generate practical implications?" Ethical validation prompts us to consider internal (i.e., team) and external (i.e., participant and reader) perspectives. Through a collaborative process, we aim to promote equitable contributions among team members. Through member checking, we aim to ensure participants are comfortable with our interpretations and dissemination efforts. Finally, process reliability steps involve documentation, team dialogue, and seeking feedback when needed.

Lessons from this study will guide others in implementing mental model elicitation activities with similarly complex phenomena. We offer that readers may utilize the interview protocol itself to initiate dialogue on ethics, DEI, and their inter-relation within their own workplace settings. The protocol could be adapted to a group-based context with a goal of developing a 'collective' mental model. Taken together, we hope this study will help other researchers employ mental models to study complex phenomena in engineering and engineering education. The ultimate findings of this work will facilitate communication across practitioner and academic groups as well as ethics and DEI scholarly communities to promote the integration of ethics and DEI in engineering curricular and workforce contexts.

Acknowledgments

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Appendix – Interview Protocol

SECTION 1: POSITIONING [~35 minutes]

Section 1a: Background [~5 minutes]
- Will you tell us a little more about the work that you do?
- (If/as needed) Will you tell me about why you do the work that you do?

Section 1b: Conceptions of Engineering Ethics and DEI [~10 minutes]

Engineering Ethics
- How would you define engineering ethics? *We are particularly interested in how you define it because we are interested in the differences in definitions, and we don't want to limit or bias you.*
- Can you give an example or two of where you have observed or experienced engineering ethics in your work? *We want to begin learning about the types of ethical experiences you have encountered. We will unpack some of your experiences later.*

Diversity, Equity, and Inclusion
- You've probably encountered terms such as diversity, equity, and inclusion. We will use the phrase, "DEI," for short in the remainder of this interview. When you think of this phrase, "DEI", what does this mean for you? *As with ethics, we are particularly interested in how you define it because we are interested in the differences in definitions, and we don't want to limit or bias you.*
- Similar as above, can you give an example or two of where you have observed or experienced DEI in your work? *As above, we do not intend to unpack this experience here, but want to begin learning about the types of DEI experiences you have encountered.*

Section 1c: Experiences at Intersection of Engineering Ethics and DEI [~20 minutes]
- Can you describe an experience you have had at the intersection between engineering ethics and DEI in your work... [(i) teaching, research, or service for academics; (ii) professional practice for practitioners]. We hope that we can unpack this experience in much more detail than the earlier experiences. With that said, please note that this can be one of the experiences you described earlier, but it does not have to be.
  - What was your role in the situation?
  - Who else was involved in this situation? What were their roles?
  - How did you approach the situation? Please walk me through the experience.
  - Why did you take the approach that you did?
  - How did you feel during this situation?
  - How did the situation end? Were there any repercussions or long-term implications of the situation? If so, what were they?
  - Did you feel prepared for this situation? If so, what helped prepare you for the situation?
    - Was there anything particularly easy or hard for you in this situation?
    - Were there any things that you wanted to know or wish that you had experienced to help you prepare for this situation?
  - Could you recap the elements of the experience relevant to engineering ethics and DEI?
  - Did this situation change the way that you think about the intersection between engineering ethics and DEI?
  - Why did you choose this experience to discuss?
  - Do you have anything else to share about this experience?

SECTION 2: DESCRIPTION [~50 minutes]

Section 2a: Mental Models and Influential Experiences [~20 minutes]
- Please take a few minutes to draw on paper the relationships between engineering ethics and DEI. As you are drawing, please try to narrate your thoughts and process aloud.
- *After around 5-10 minutes or when participant stops drawing, ask*, If you are comfortable, please hold up your drawing as we would like to take a screen shot of your drawing at this time. We will also revisit this at the end of the interview.
- In light of your drawing, we have a few additional questions to further inquire into your thoughts about ethics and DEI connections. Some of these aspects you have may already mentioned during the process drawing.
  - What **ethical responsibilities** do engineers have in relation to DEI concerns and how does your graphic depict that?
  - To what extent is your mental model representative of other engineers' mental models (potential)
- What has influenced your... understanding of the intersection between engineering ethics and DEI?

Section 2b: Perceptions of a DEI Organizational Issue [~15 minutes]
Next we are going to talk about common "DEI" issues in organizations. While we have labeled these issues as DEI issues, we are interested in hearing if you think that any of these issues are also *ethical* issues in nature. As a friendly reminder, everything in this interview is voluntary and you may choose to forego answering any questions. We are particularly interested in your perspectives or experiences but we also understand that sharing your perspectives can be challenging and uncomfortable.

- **Retention of Underrepresented Employees:** An organization has a difficult time retaining underrepresented employees. There is a revolving door of underrepresented employees leaving the organization, but they do not stay for longer than one year. The manager indicates that many of these employees complain of an environment that is not welcoming or inviting to them.

Imagine that you are a current engineer working in this company.
- What would you do in this situation? Please walk me through your thinking.
  - Prompting questions if/as needed:
    - Who else would you involve in this situation? Why these individuals?
- How did you feel thinking about your response?
  - Prompting questions if/as needed:
    - Was there anything particularly easy or hard for you in this situation?
    - Were there any things that you wanted to know or wish that you had experienced to help you think through your response?
- Do you perceive this as an engineering ethics issue? Why or why not?
  - *If no, do you perceive this as an *ethical or moral* issue? If no, why not?
- What ethical responsibilities are applicable in this situation?
- What elements of the experience are relevant to both engineering ethics and DEI?

Section 2c: IEEE Code of Ethics [~15 minutes)
- Next we are going to talk about engineering ethics codes. How should DEI be incorporated into engineering ethics codes, if at all? Please feel free to speak generally or (if applicable) about your own professional discipline,
- We are going to talk briefly about your perceptions of IEEE's most recent (2020) ethics code.

*Show participant the IEEE clause: https://www.ieee.org/about/corporate/governance/p7-8.html

org/uploadedFiles/About_ASCE/Ethics/Content_Pieces/asce-coe-oct-2020.pdf
Please take a minute to review the clause. [see next page]
- Do you think any of these considerations are inappropriate in an engineering ethics code? If so, which?
- In the context of your own professional discipline, do you think that DEI should be emphasized within ethics codes? If yes, how, exactly? If no, why not?
- [ask if participant has emphasized organization's code of ethics] In the context of your own organization, do you think that DEI should be emphasized within organizational codes of ethics? If yes, how, exactly? If no, why not?

Section 3: Summative [~10 minutes]
- Please take a few minutes to revisit your mental models drawing from earlier. Please let me know if you would like to update or clarify any of your items from this in light of our discussion.
  - Ethics definitions: *Throughout this interview, we have been using the term "engineering ethics." [if applicable] Through our conversations, we have not unpacked this term. We have a few pointed questions about the term ethics and are interested in your thoughts about potential differences.*
    - How do you think engineering ethics differs from "professional ethics", if at all?
    - How do you think engineering ethics differs from "ethics", if at all?
    - How do you think ethics differs from morality, if at all?
    - Is distinguishing between these 'types of ethics' important for engineers?

- Throughout this interview, we used the packaged phrase, "DEI." [If participants did not differentiate between DEI terms] Through our conversation, we did not unpack different framings of DEI and we would be interested in your closing thoughts:
  - Are there important differences between D, Diversity, E, Equity, and I, Inclusion that we ought to consider when using this combined phrase in engineering?
  - When considering engineering ethics connections, are D, E, and I equally important? If yes, can you explain why? If not, which terms are more or less important and why?
  - Are there other DEI-like terms that you consider when thinking about this conception? [don't provide examples to folks]
    - Why is this/are these other conceptions important to add?
    - How do adding these conceptions to "DEI" potentially influence your mental model?
- Do you have any concluding thoughts or comments on engineering ethics and DEI? Perhaps things you just remembered or didn't have an opportunity to mention?